# Recent DIS Results from Jefferson Lab:

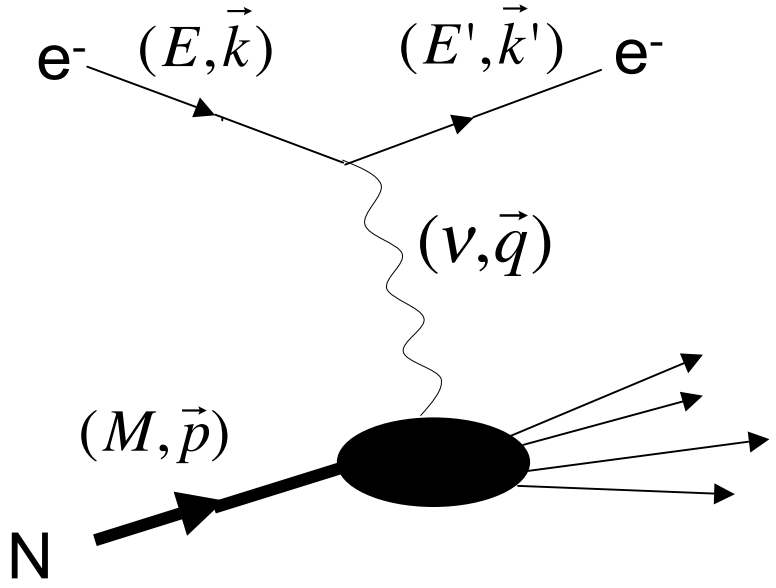
## $A_1^n$ at High x
## and
## the $Q^2$-dependence of $g_2^n$

## PANIC '05

Todd Averett
College of William and Mary
Williamsburg, VA USA

# Polarized Inclusive Electron Scattering

- Scatter longitudinally polarized electrons from polarized nuclei (fixed target).
- Virtual photon probe of quark structure.
- At large $Q^2$, interaction dominated by scattering by single, asymptotically-free quark.

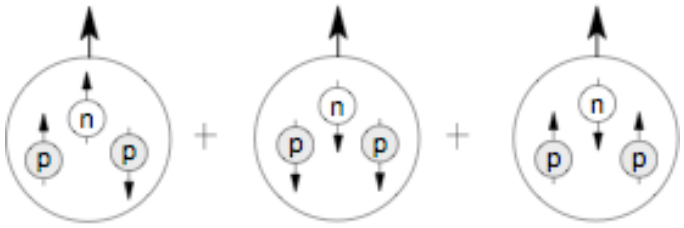



$$Q^2 = \vec{q}\cdot\vec{q} - \nu^2 \quad -(\text{four - momentum transfer squared})$$

$$x = \frac{Q^2}{2M\nu} \quad (\text{fractional momentum of struck quark})$$

# Formalism

- Inclusive polarized electron scattering from a $^3$He target polarized longitudinal or transverse to electron helicity.
- Polarized $^3$He --> polarized neutron target.
- $^3$He ground state:




*S* state (89.93%) + *D* state (8.75%) + *S'* state (1.26%)

- Measure polarized cross-section differences-- extract structure functions/asymmetries.

$$\Delta\sigma_{\parallel}(\nu,Q^2),\ \Delta\sigma_{\perp}(\nu,Q^2) \Rightarrow g_1(x,Q^2),\ g_2(x,Q^2),\ A_1(x,Q^2),\ A_2(x,Q^2)$$

# Physics of $A_1$, $A_2$, $g_1$, $g_2$

## Virtual photon asymmetries

$$A_1(x,Q^2) \equiv \frac{\sigma_{1/2}^T - \sigma_{3/2}^T}{\sigma_{1/2}^T + \sigma_{3/2}^T}$$ → absorption of transversely polarized photons

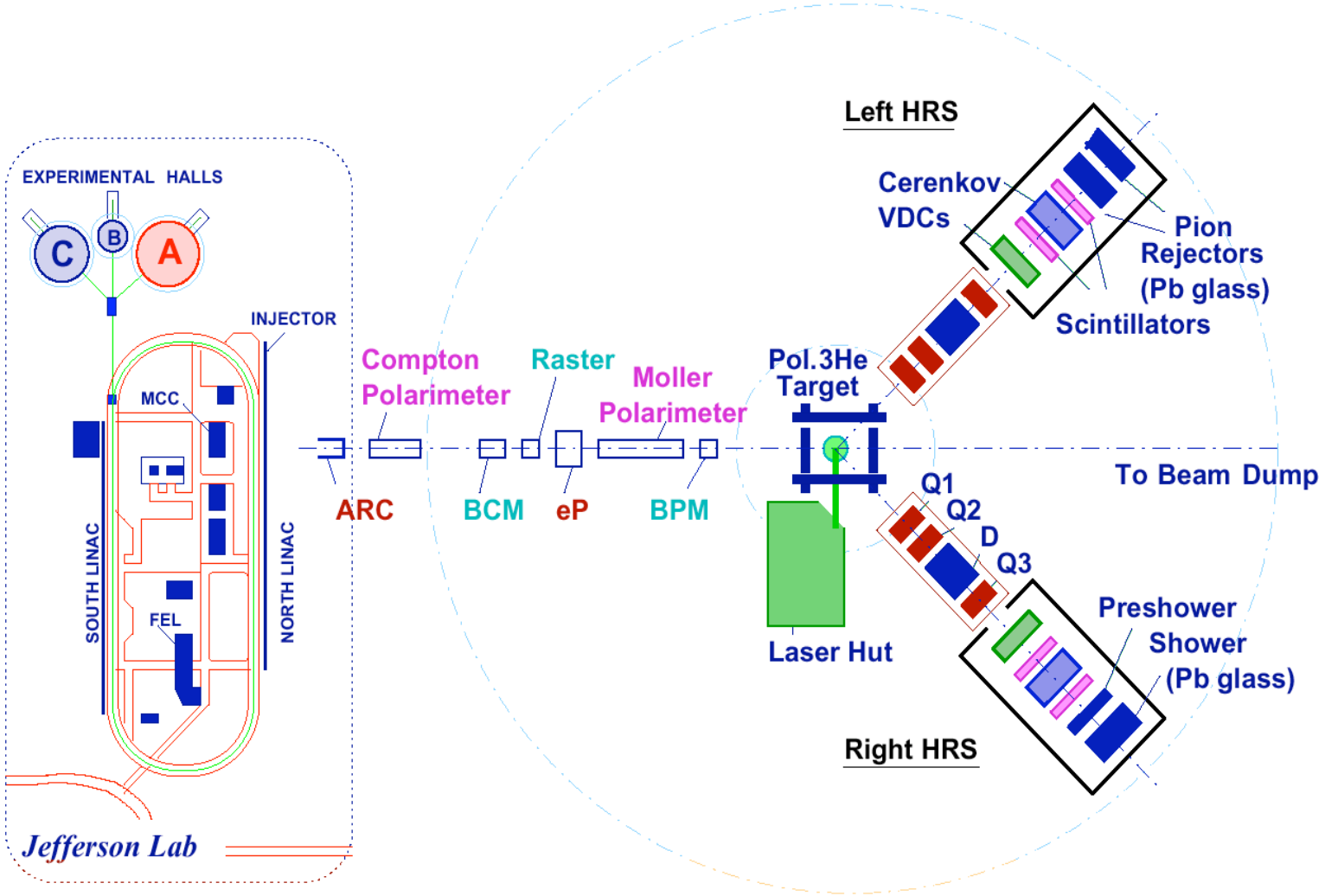
$$A_2(x,Q^2) \equiv \frac{\sigma^{LT}}{\sigma_{1/2}^T + \sigma_{3/2}^T}$$ → longitudinal-transverse interference

## Spin structure functions

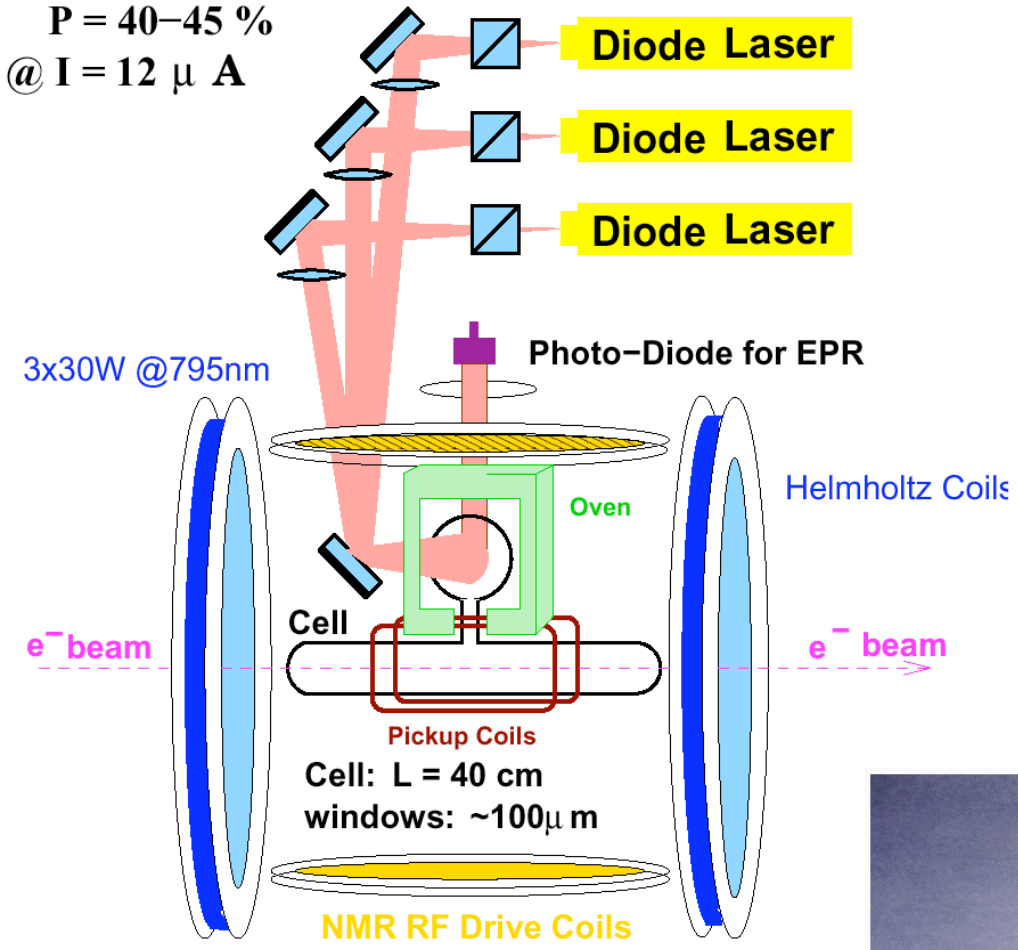
$$g_1(x,Q^2) = \frac{1}{2}\sum_i e_i^2 \Delta q_i(x,Q^2)$$ → At large $Q^2$, related to polarized quark PDF's. Non-pQCD higher-twist contributions suppressed by factors of $1/Q^n$.

$g_2(x,Q^2)$ → Asymptotically-free AND higher-twist contributions enter at same order for any $Q^2$.

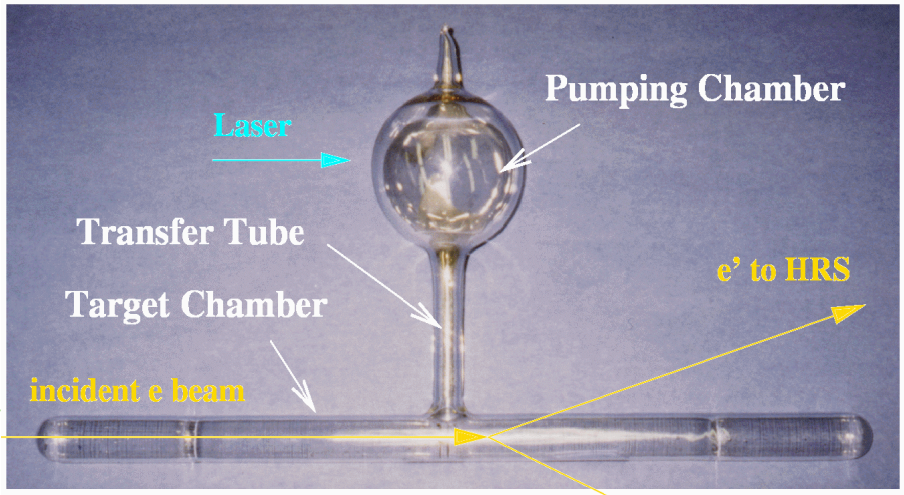
# Jefferson Lab HALL A



# Hall A polarized $^3$He target




- **Both longitudinal and transverse polarization (and soon vertical)**
- **NEW hybrid K/Rb cells give faster spin-up time, higher polarization**



# $A_1$ in the valence quark region

- At high $x_{Bj}$ and large $Q^2$, valence quarks dominate nucleon structure.
- Simple SU(6) symmetric model predicts constant $A_1^n = 0$, $A_1^p = 5/9$.
- RCQM with hyperfine SU(6) symmetry breaking predicts $A_1^{n,p,d} \to 1$ as $x \to 1$.
- pQCD models assuming Hadron Helicity Conservation (HHC) also predict $A_1^{n,p,d} \to 1$ as $x \to 1$.
- Most models predict positive $A_1$ at high x and positive slope as $x \to 1$.
- Previously no precise data for $A_1$ at high x.
- Previous data for $A_1^n$ at low-x slightly negative.

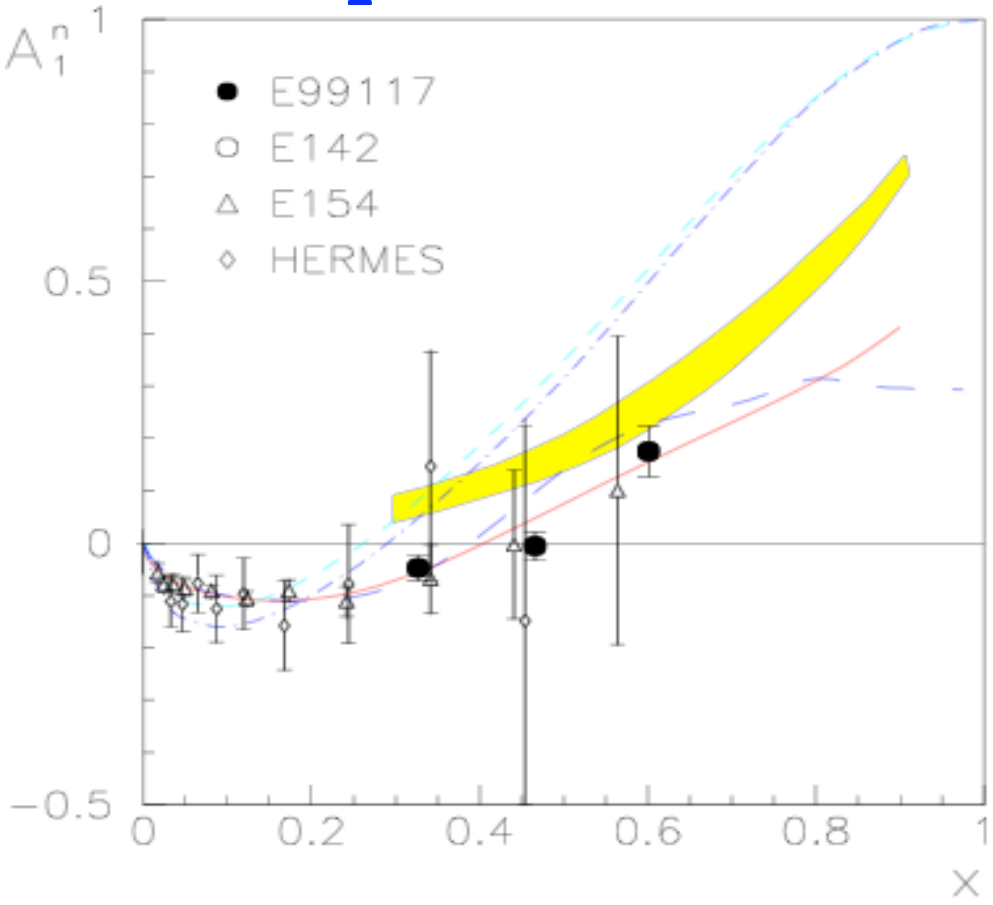
# Jefferson Lab $A_1^n$ results

- $Q^2$=2.7-4.8 GeV$^2$
- Clear zero-crossing; positive slope.

★ Data don't agree with pQCD models assuming hadron helicity conservation with zero quark OAM (two upper curves).

★ Better agreement with models w/o HHC: RCQM (yellow band), NLO QCD fit constraint (red line), and statistical model (lower dashed curve).

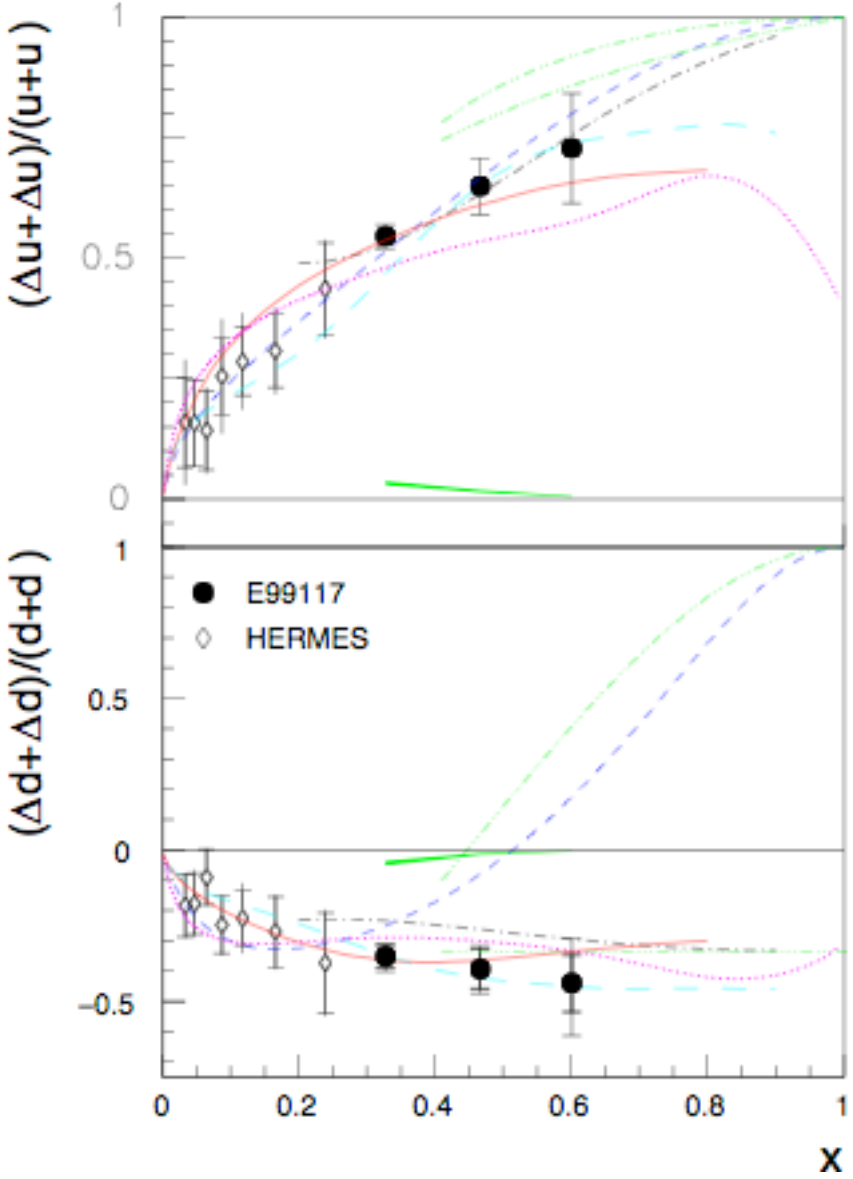
★ ➡ non-zero quark OAM.




X. Zheng et al., PRL **92**, 012004 (2004); PRC **70**, 065207 (2004)

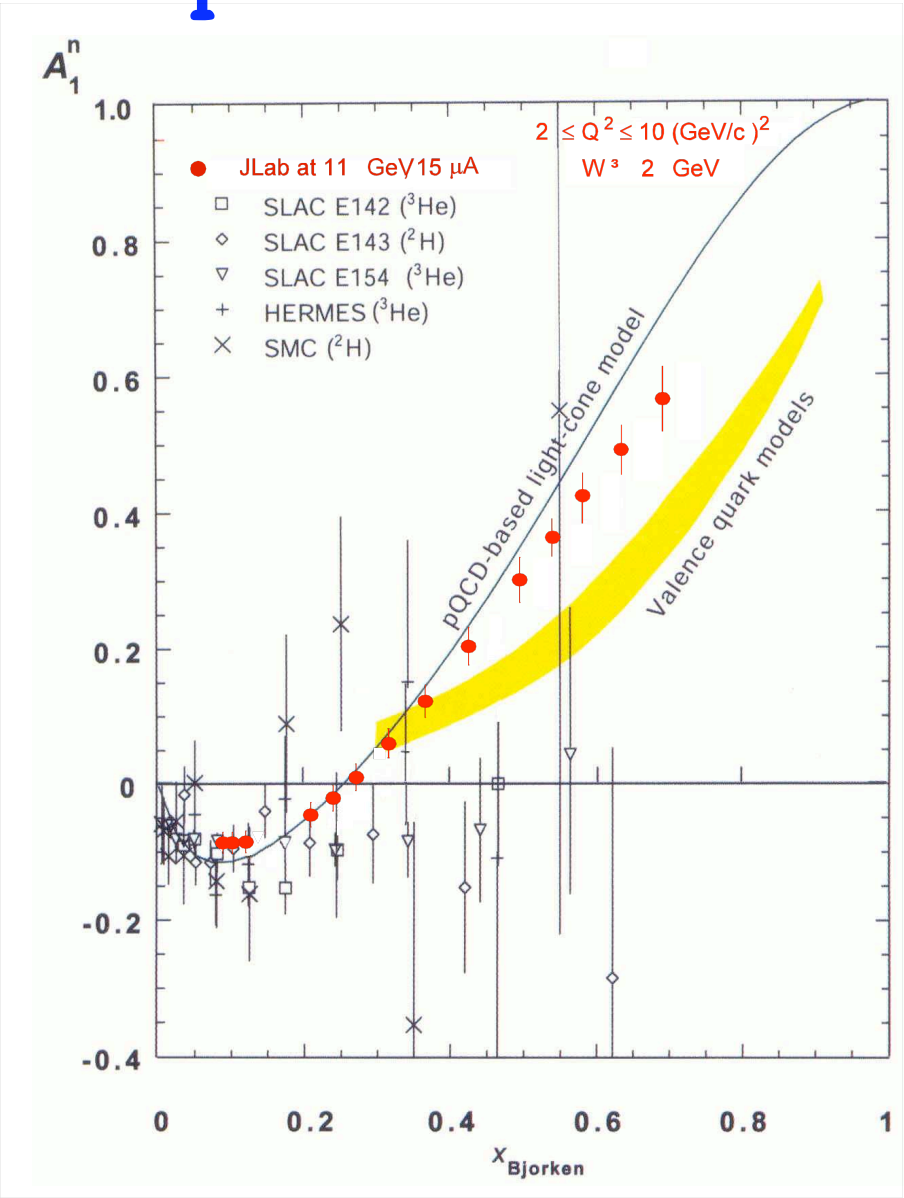
# Extracting $\Delta u/u$ and $\Delta d/d$ from neutron results

- Assume s-quark contrib. small for x>0.3.
- Ignoring $Q^2$-dep., use JLab $g_1^n/F_1^n$ and world data for $g_1^p/F_1^p$.
- u-quark results agree with models.
- d-quark results agree with most models, but not with pQCD assuming HHC (blue dashed line).



# The Future: $A_1^n$ at 11 GeV

- Anticipated upgrade of Jefferson Lab to 11 (12) GeV beam with new spectrometer.
- Definitive measurement of $A_1^n$ at high-x with polarized $^3$He.



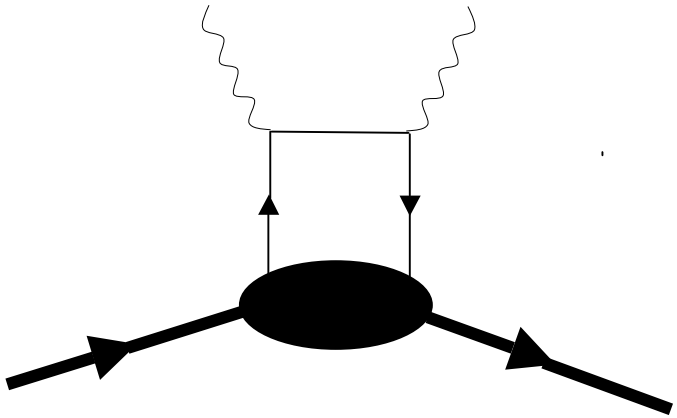
# $Q^2$-dependence of $g_2^n$

- Precise measurement of $g_2^n$ at $x \approx 0.2$ at five values of $Q^2$ between 0.57 - 1.34 GeV$^2$.
- Unlike $g_1$, it has no simple parton model interpretation; contributions from quark-gluon correlations not suppressed relative to asymptotically-free contributions as in $g_1$.
- Wandzura-Wilczek expression from OPE allows calculation of twist-2 contribution from "free-quark" scattering.

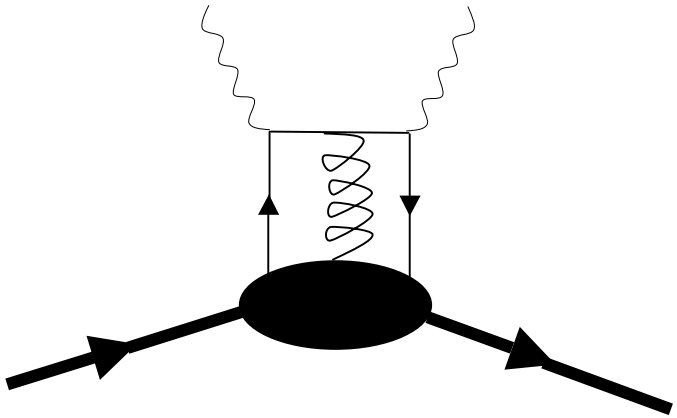
$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 \frac{g_1(x',Q^2)}{x'} dx'$$

- Deviation from $g_2^{WW}$ quantifies higher-twist contributions.

# Higher-Twist Contributions



twist-2 = scattering from asymptotically-free quark

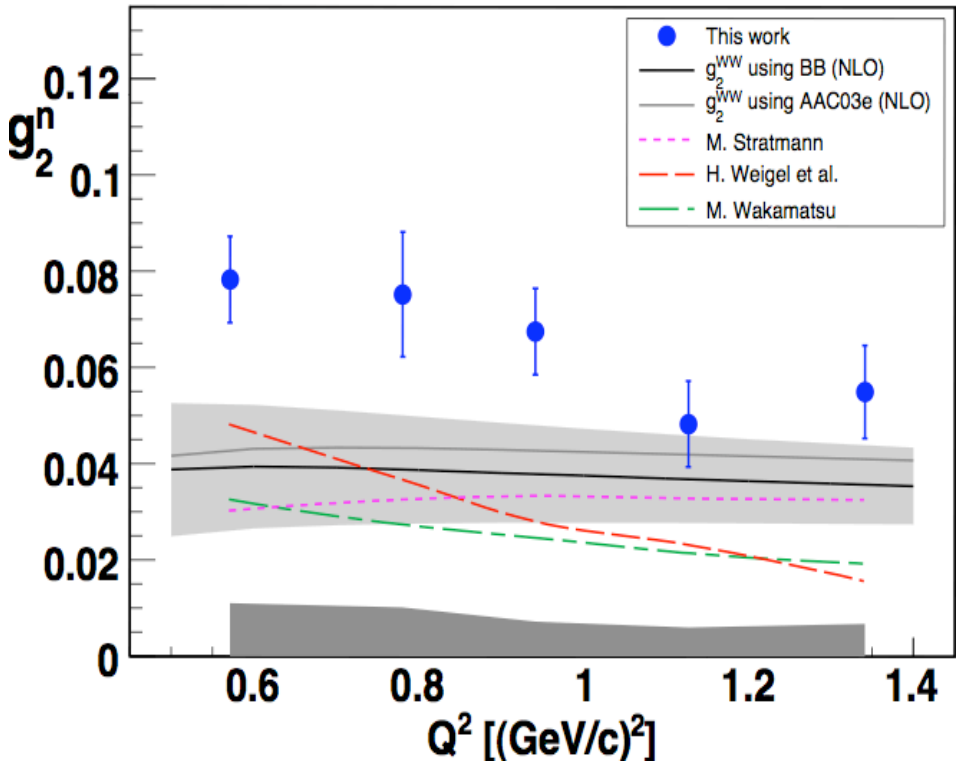


twist-3 = scattering from quark that is simultaneously exchanging gluon with nucleon

# Jefferson Lab results for $g_2^n$

- Evidence of HT effects.
- Fit assuming twist-3 gives:

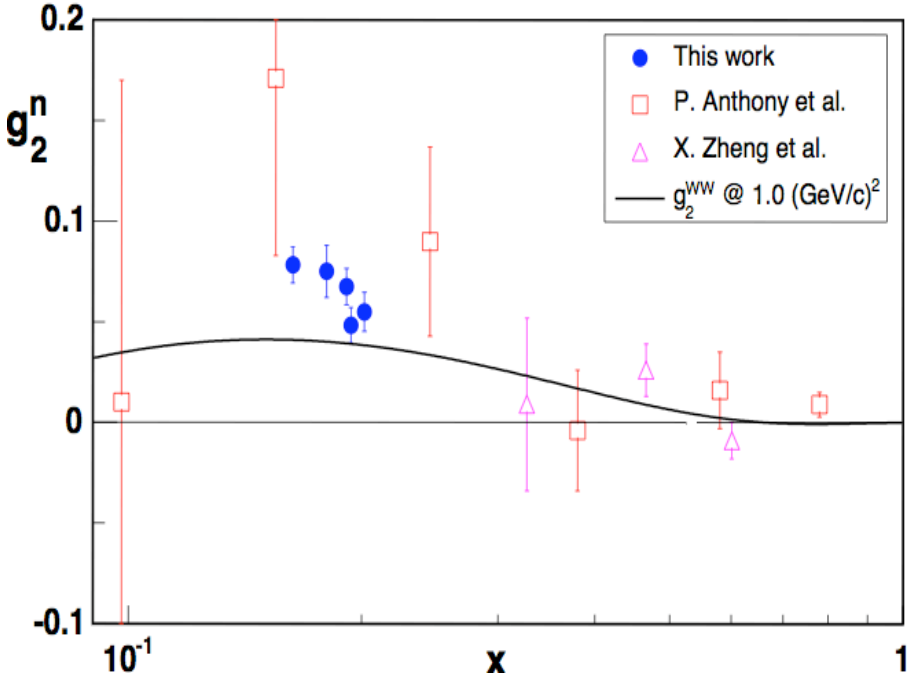
$$C_{tw-3} = 0.0262 \pm 0.0043\ (stat.) \pm 0.0080\ (sys.) \pm 0.0099\ (g_2^{WW})$$

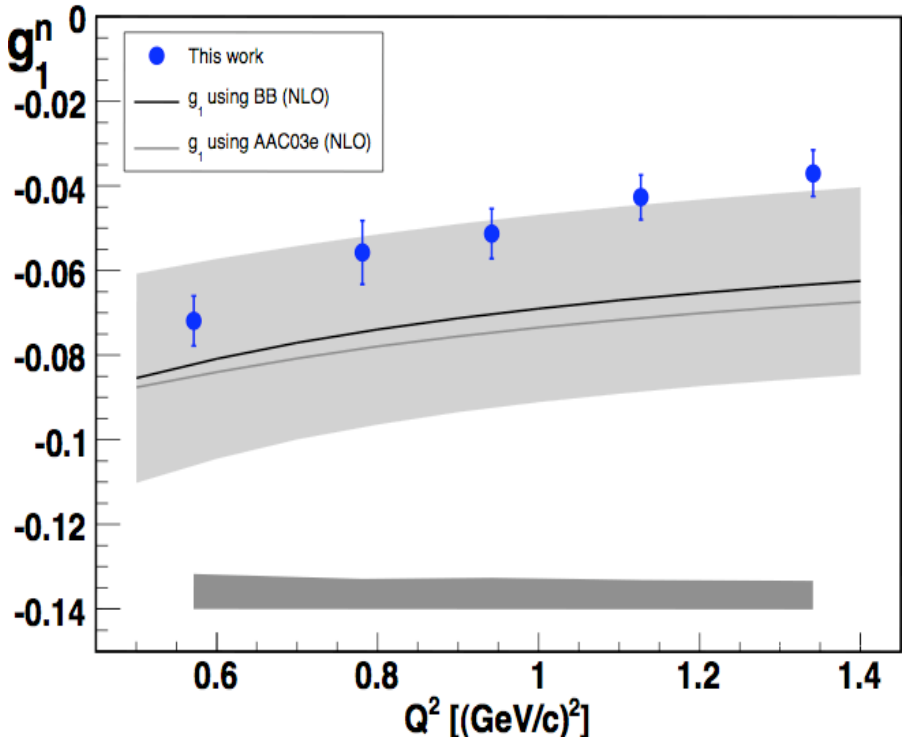



K. Kramer et al.
PRL **95**, 142002 (2005)

# $g_2^n$ results con't

- Factor of > 10x improvement in $g_2^n$ statistical uncertainty.
- Measured $g_1^n$ consistent with NLO fits to world data, evolved to these $Q^2$; indicates no HT effects within uncertainties.



# Summary

- New precision data on neutron spin structure functions.
- Zero-crossing and positive slope seen in $A_1^n$; data consistent with models allowing quark OAM.
- Evidence of HT effects clearly seen in $g_2^n$.
- Precision data from JLab 12 GeV upgrade essential to pin down high-x region, test lattice and pQCD calculations of $Q^2$-dependence of moments and structure functions.